CAPABILITIES

Microgrid-Ready Solar PV

Microgrids are the wave of the future. Serving areas as small as a single building to an entire installation, campus, or community, microgrids are electrical systems that can interconnect and interact with the utility grid or operate independently on locally generated power. Microgrids allow hospitals, data centers, or other critical facilities to operate even during a utility outage. The U.S. Department of Defense (DoD) is actively pursuing microgrids as a means to achieve energy surety and security at military facilities nationwide. With the integration of renewable energy sources, microgrids can strengthen energy security.

The solar energy industry is one of the fastest growing industries in the United States. In 2014, 6.2 GW of solar PV was installed, up 30% from 2013, making it the largest year ever in terms of PV installations.[1] For solar project designers future microgrid considerations are becoming increasingly important.

The current number of installed microgrids is small, but predicted to grow significantly over the next three years. Is your solar project microgrid-ready?

Upfront Planning

Designing new solar projects to be 'microgrid-ready' enables the U.S. DoD, other federal agencies, and the private sector to plan future microgrid initiatives to utilize solar PV as a generating resource. This fact sheet provides background information with suggested language for several up-front considerations that can be added to a solar project procurement or request for proposal (RFP) that will help ensure that PV systems are built for future microgrid connection.

Microgrid-Ready

The PV system may be a resource in a future microgrid that can operate when utility disturbances or outages occur. This microgrid could include conventional (engine) generators, other renewable resources and/or energy storage. If there is no isochronous generator in the system that sets microgrid frequency and voltage, a "master inverter" with battery storage can be selected that will provide this function. Suggested RFP language and functionality includes:

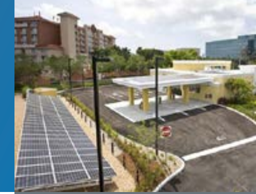
- The inverters and their functionality as distributed resources in planned electrical islands shall comply with applicable provisions described in IEEE Std 1547.4-2011.
- Selected PV inverters [typically the larger inverters] shall be multi-mode DC to AC inverters capable of switching between grid-interactive mode and microgrid (intentional island) mode. These inverters, in conjunction with a system supervisory controller, shall be capable of bi-directional real and reactive power flow.
- Sufficient space shall be provided for future energy storage equipment.
- Spare communications raceway(s) shall be installed that could be used to route future communications cabling to the point of common coupling, central controller, or other pertinent equipment.

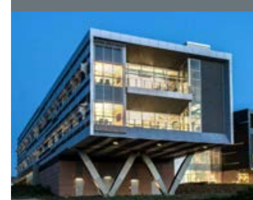
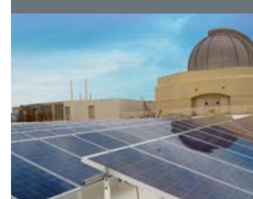
Inverters for Grid Support

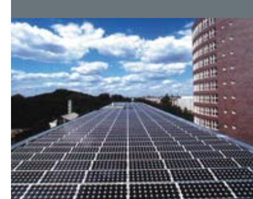
The core job of a PV inverter is to convert the DC from solar cells into AC, but other inverter functions can be useful to both the PV system and microgrid. For example, if PV generation needs to be reduced to balance generation and load in a microgrid, the inverter can curtail PV output via control set-point(s).

Inverters also have the capability to "ride through" frequent minor disturbances, as in the case of weak grids or microgrids. Current standards require that inverters disconnect the PV system when grid frequency or voltage falls outside a specified range. Adjustments to inverter trip levels and clearing times can allow the PV system to stay online and respond accordingly to relatively

1. *www.seia.org/research-resources/solar-market-insight-report-2014-q4*





NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

short-term, minor events. In some cases, this function can actually help the grid to self-heal from a disturbance. Suggested RFP language and inverter functionality include:

- The inverter shall be capable of curtailing its output in logical steps, with controllable ramp rates, in response to commands from a microgrid controller or other source.
- The inverter shall have adjustable trip limit and clearing capabilities as determined by electrical studies, and as permitted by IEEE Std 1547a-2014. Important capabilities include fault ride-through to stay on-line during transient grid disturbances, such as sags and swells, and extended operating voltage and frequency ranges to avoid nuisance tripping.
- The inverter shall be capable of real-time data logging, alarm reporting, and responding to control signals via [site to determine communications method and protocols] from a remote power system controller.

Power Factor Considerations

PV systems can affect the power factor (PF) in an electrical system. The solar PV project should be analyzed for impact to power factor from a technical and economic perspective in grid connected and microgrid modes. If it is determined site load PF will be affected, inverters, dedicated power electronics, or traditional capacitor banks can provide PF and reactive power (VAR) support.* The full cost of all the options should be considered, such as operations and maintenance, controller costs, and upsizing the inverter to be able to maintain the same kW and source VARs. Suggested RFP language and functionality includes:

- Inverters shall be capable of sourcing or sinking reactive power for the purpose of improving power factor and mitigating or eliminating monthly power factor charges. Reactive power levels (absorption or supply) shall be either programmed locally (autonomous control) or be implemented upon receipt of a set-point command provided by a remote controller. The control system shall adjust inverter reactive power need based on actual system conditions. Inverter reactive power capacity shall be determined by the Contractor following evaluation of load data, PV system size, and utility rate schedule. The inverter shall be capable of sourcing VARs even when daylight is not present. Oversizing the inverter to allow for both reactive power and planned real power requirements may be necessary.

If power purchase agreement or other contract with private ownership is involved, include the following:

- The Contractor shall propose how they should be compensated for any lost real power kWh in exchange for sourcing VARs. (For example, use the inverters to record potential kWh vs. actual kWh.)

Conclusion

What the future holds for renewable energy microgrids depends on many variables: regulations, incentives, the future role of utilities, and more. But if current policy, technology, and pricing trends are any indication, microgrids are destined to provide a secure, clean compliment or alternative to the conventional power grid in the very near future. Is your solar project microgrid-ready?

NREL has experience and expertise supporting solar PV and microgrid projects. NREL can provide technical assistance, project development support, and testing at its Energy Systems Integration Facility (*www.nrel.gov/esif/*) to ensure that your PV project is microgrid-ready.

** Note, however, that the switching of capacitors could result in transient overvoltages in the site's distribution system, whereas an inverter can ramp in VARs.*

NREL knows solar. NREL knows microgrids.

NREL has partnered with Raytheon to successfully demonstrate an advanced microgrid system that draws on batteries and solar photovoltaic energy for its power. The demonstration will lead to a pilot system to be installed at Marine Corps Air Station (MCAS) Miramar.

The NREL team demonstrated the actual performance of the microgrid system installation at its Energy Systems Integration Facility and refined its operation prior to it being installed in the field, greatly reducing the risk of investing in the system. Using this pilot system's technology, the fielded microgrid at MCAS Miramar will be able to maintain power to base facilities under many adverse conditions—including loss of the local power grid. Building on this pilot project NREL is supporting execution of a larger $18 M U.S. DoD funded microgrid at Miramar.

For support or additional information, contact Sam Booth at 303-275-4625 or samuel.booth@nrel.gov.

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

NREL/FS-7A40-64582 • July 2015

NREL prints on paper that contains recycled content.

Photos (page 1, top to bottom) From Turner Construction; by Dennis Schroeder, NREL 31573; by Dennis Schroeder, NREL 21794; by Dennis Schroeder, NREL 26211; from Orlando Utilities Commission, NREL 18715; by Dennis Schroeder, NREL 28845; from BP Solarex, NREL 08861